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The Geology of the San José District,
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THE GEOLOGY OF THE SAN JOSÉ DISTRICT, TAMAULIPAS, MEXICO

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[PLATES VIII-XVIII]

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I. INTRODUCTION. ACKNOWLEDGMENTS

In 1899, Mr. E. D. Self, a graduate of the School of Mines of Columbia University sent a small suite of peculiar eruptive rocks, which occur near the mines at San José, Tamaulipas, Mexico, to Professor Kemp. They were at once recognized as tinguaita and nephelite syenite, of great scientific interest. A second shipment from Mr. Self of a larger series showed the presence of camptonite and andesite. In December, 1901, the writer accompanied Professor Kemp to San José with the object of studying the copper ores and the neighboring eruptive rocks. It was arranged that the writer should take up the petrographic investigation of the latter, and the results are here submitted. He cannot sufficiently acknowledge his indebtedness to Professor Kemp, not only for the opportunity so generously given him of studying the rocks petrographically, but also for encouragement of every kind during his work. Every facility was afforded him by Mr. Self, to whom his grateful acknowledgments are due, as also to Mr. W. H. Nichols, Jr., president of the San Carlos Copper Company. Dr. H. S. Washington very kindly analyzed specimens of the nephelite syenite, and of the tinguaita. The writer is anxious to express his obligations to him for this, and for invaluable assistance in the analytical work and calculations. The work was carried on in the geological laboratory of Columbia University.

II. TOPOGRAPHY

The town of San José, on the property owned by the San Carlos Copper Company, lies in an elliptical depression narrowly bounded by mountains on every side. The valley occupies about nine square miles. Its lowest point is 2,250 feet above the sea. The interior rounded hills near its center are five and six hundred feet higher. Anacuas and Ladinás, which shut in the view to the north are limestone mountains reaching altitudes of 3,000 and 3,200 feet respectively. The sag between them is inconsiderable, but there is a deep cut in the ridge immediately to the east of Anacuas. The road from San José to the town of Linares on the line of the Mexican Gulf Railway follows the main stream channel through this valley. Immediately to the east of San José is a line of mountains stretching for four miles from Mt. Anacuas to the south. Mt. Armadillos, which obtains an elevation above sea-level of 3,500 feet, is the highest and most striking point to the east. (See Pl. XV.) On the north-western and western sides of the hollow in which San José lies, Mt. Tinaja, altitude 3,400 feet, and Mt. Parreño, altitude 3,500 feet, stand forth prominently as the highest points in the ridge which extends for seven miles southwardly from Mt. Ladinás. From Mt. Parreño it continues in that direction for a mile and a half until it meets the line of the Baril Mountains almost at a right angle. The Baril range terminates in two bold crags on the east where it is separated from Mt. Armadillos by a deep river valley. It extends westwardly from this point for a distance of two and a half miles with an average elevation of 4,800 feet to Mt. Baril, shutting in the San José valley on the south. From Mt. Baril the ridge turns to the southwest, becomes extremely sharp, and after extending for two miles in this direction bends in a great half circle and joins the northeastern spur of the Pic de Diablo. This mountain is 6,000 feet high. Its summit is formed by the union of several extremely sharp almost inaccessible craggy ridges. Its northern face which is bold and picturesque, looks down on the deep rounded valley that has been carved out of the mountain mass by the two

forks of the Arroyo Grande. The north fork of this stream heads up under Mt. Baril and the Baril Range forms the divide on the north between it and the San José valley. The south fork of the Arroyo Grande has its source under the divide formed by the continuation southwestwardly of the Baril Range. The bottom of the valley of the Arroyo Grande is nearly three thousand feet lower than the Pic de Diablo. By the profound erosion which has taken place in this mountain valley the divide between the streams flowing eastwardly from the San Carlos Range and those which flow westwardly has been pushed far to the west. At the head of the Bocca de Alermos Arroyo, which is the stream in the next great valley to the south, the main divide has been driven well over toward the eastern side of the range. (See Pl. XVIII.) The valley of the Bocca de Alermos Arroyo opens from a rock-walled canyon, as one proceeds up stream into a broad elliptical amphitheater covering about six square miles. This great depression lies well in toward the center of the mountain mass. From the Pic de Diablo the San Carlos Range gradually declines toward the southeast. It extends in this direction for nine or ten miles from the Bocca de Alermos, and throughout its course exhibits the characteristic mountain forms which are found in the long lines of precipitous crags and sharp trailing ridges of the Pic de Diablo. The San Carlos Mountains, with their foot-hills, are a unit on the great plains of north-eastern Mexico. (See Pl. XVI.) The lesser mountains which border on the central chain commonly show forms of high relief. When they have been carved out of sedimentary rocks their sides are invariably steep. They are at times precipitous along lines of faulting. Their tops are continued by three or four shoulders as pyramidal forms. When composed of igneous rock they are often nearly perfect cones. The lowest outlying spurs of the range run down to the plains in rounded contours, their line of slope being that of a parabola. The San Carlos mountain mass is separated from the Sierra Madre Mountains by a great plain, extending far to the northeast and to the southwest. The distance across it between the two ranges is fifty miles. When one travels across this plain it is

seen not to be a unit, for erosion has proceeded far enough to level away a considerable space on either side of the main rivers and lesser streams. These level stretches are all situated at the same altitude. The ridges and rounded buttes which stand above them rise to a uniform height so that their tops are parts of a second common plane.

The mountain slopes of the interior valley in which San José is situated are nearly as steep as loose material can stand. The arroyos have commonly made V-shaped cuts with vertical walled trenches at the point of the V. The climatic conditions which affect erosion are peculiar, and deserve to be mentioned. The surrounding country is very dry, almost arid, but the San Carlos Mountains are high enough to be often surrounded by clouds. The dews are commonly heavy, and slight showers may fall once or twice in a fortnight, but the main portion of the annual rain supply comes down in one or two weeks of hard rain. At such times the torrents are immediately concentrated in the mountain gullies, and twenty minutes after the first drops fall the streams in the center of the valley begin to rise. Many which are dry throughout the greater part of the year then carry three or four feet of water, and their currents are so rapid that they are able to urge along boulders which are over two feet across. With continued rain the streams may rise five and six feet, and be able to transport a great amount of detrital materials. Fifty thousand tons were removed in this way from a mine dump in twenty-four hours.

The streams in that portion of the valley which is near the town of San José and immediately to the northwest of it, have lowered their beds for 15 or 20 feet through a rudely stratified deposit of angular and subangular rock fragments. This represents the accumulation at low levels of the loosened material which is everywhere in process of transit down the steep slopes in the central portions of the valley. The andesite, which is the country rock here, is capped by a very scanty cover of soil in most places, while over wide stretches the bed rock comes to the surface. This is covered uniformly by fragments which have weathered away from its superficial portions. These have

a maximum size of six inches. Under the action of gravity, and the occasional urging of torrential rains they are slowly traveling down to the low ground in the valley bottoms. The conditions by which weathering goes on in the San José region are those in which a prominent part is played by the daily temperature changes. Even in winter the extreme of cold is seldom much below the freezing point, but the air is dry and the nights are invariably cool. The maximum diurnal temperature change in the exposed rock masses is not less than 90° F. There can be no doubt that in the San José district that form of weathering which is accomplished by the alternate expansion and contraction of rock masses by heat and cold is of unusual importance. The riving action of frost is here reduced to a minimum. In the Baril Mountain range many great scales of the nephelite syenite have been stripped away from the exposed masses.

The drainage of the San José valley is toward the north by a stream which runs along the eastern flank of Mt. Anacuas, and to the east by a trunk stream which leaves the valley under Mt. Ladinas. The divide between the two systems coincides very nearly with a line drawn from Mt. Armadillos to Mt. Baril. About a quarter of the whole valley is drained by the second stream. Many of the lesser divides are mere knife edges and the Baril Range which lies between the drainage of the San José valley and those streams which flow into the north fork of the Arroyo Grande is so narrow that any further cutting must lower its crest line. At no point, however, except near Mt. Ladinas and Mt. Anacuas, have the arroyos which are everywhere gnawing headward against the ridge surrounding the valley of San José succeeded in tapping its drainage.

The Arroyo Grande rises against the Pic de Diablo six miles to the south of San José and takes an easterly course. (See Pl. XVII.) The amphitheater which it drains, with the open valley before it, bears a curious superficial resemblance to the cirques and tributary valleys in a country which has been the home of vigorous local glaciers.

The Bocca de Alemos Arroyo rises beyond the Pic de Diablo

to the south. It receives the drainage from a much larger area than the Arroyo Grande does, and makes its way to the plains to the west through an extended canyon cut in limestone. The interior valley at its head is similar to that about San José.

III. STRATIGRAPHY. STRUCTURE

It will be seen by an inspection of the map that the sedimentary rocks surround the central mass of andesite, adjacent to the town of San José, almost entirely. The Baril Range appearing on the south is nephelite syenite. The sedimentary series about San José is composed of limestone and shale. The blue limestone is the important member of the series. It is a heavy bedded rock, in regular, gently dipping layers, capping the andesite on mounts Parreño, Tinaja, Ladinas, Anacuas and Armadillos. The limestone is siliceous, and has a dense even grain. It scarcely ever shows traces of organic life. Two poorly preserved fossils were found in it, a belemnite and an exogyra. It is a part of the great mass of Cretaceous sediments in eastern Mexico. Rarely shaly layers, an inch or less in thickness, are met in the limestone. They were carefully examined for fossils but none were found. The limestone once extended over the entire San José region. It has been stripped away on all sides from the andesite beneath it. The dips, as indicated on the map, are radially outward from San José at every point. They average nearly 35° . The mass of andesite is a laccolith. These relations are expressed in the sections [Plate II]. A few small outliers of the limestone have been left standing over the andesite near San José. A much larger remnant is found a mile to the south above Bretaña Creek. Three or four small outliers, besides these, are found to the south near the Baril Range. These are all identical with the main body of limestone. Like it they are but slightly affected, near the contacts, where they stand against the igneous rock. Rarely, the limestone is changed to marble for a foot and a half from the contact. Smaller limestone inclusions in the andesite have been thoroughly metamorphosed and made over into garnet

(grossularite) and vesuvianite. These are found by the score over the whole region. They offer most interesting problems in contact metamorphism. The main mass of the limestone gives evidence of the dynamic effects of laccolithic intrusion. The siliceous bands, which appear as dense flinty included masses half an inch thick and a foot or more in length may often be seen to have been broken and faulted repeatedly. These effects were not observed at a distance from the andesite. It is impossible to say how thick the cover over the laccolith was. It is believed that the igneous rock was viscous rather than liquid. The amount of silica present, sufficient to allow for the formation of free quartz, is evidence in favor of this view. The laccolithic intrusion is of comparatively small extent with moderately high doming. No evidence could be gathered which would help decide the question as to whether or not the incoming of the molten rock was aided by the relief from pressure consequent to the initial stages of anticlinal folding. The limestone at a short distance from San José lies nearly horizontal, but the shaly member of the series constantly shows pressure effects. Exposures of this rock are found to the east of the Pic de Diablo, replacing the limestone in the foothills of the San Carlos Mountains. It is here a drab or gray coarse shale, thinly bedded, and everywhere broken by countless joint planes. These give it a platy parting horizontally. The vertical joints are frequently so numerous as to cut the shale up into small pieces. These fragments two inches or more in diameter are quickly broken out and rounded by the agencies of weathering.

In the slopes of Mt. Ladinás, and on Mt. Armadillos, as well as various points to the southwest and southeast of it the andesite has broken through the limestone cover in the form of dikes.

IV. STREAM ADJUSTMENT

The phenomena of drainage peculiar to eroded laccoliths have recently been treated in a paper by Dr. T. A. Jaggar, Jr., in the Twenty-first Annual Report of the U. S. Geological Sur-

vey, on "The Laccoliths of the Black Hills." The laws governing drainage changes on eroded laccoliths are there developed in a most interesting manner. The drainage of the San José region is similar to that of the Citadel Rock type, but at San José two originally radial streams have taken possession of the dome and cut into the exposed mass of andesite. The stream which flows past Mt. Anacuas is working at a lower level than that one which lies beside Mt. Laureles. The divide between the two drainage systems is slightly to the northeast of a line joining Mt. Armadillos and Mt. Baril. It is a low divide, and with a few feet of forward cutting capture of the Laureles drainage would result.

V. FIELD RELATIONS OF THE IGNEOUS ROCKS

The igneous rocks of the San José region are granitoid nephelite syenite and diorite, andesite, effusive basalt, and dikes of tinguaita, diabase, camptonite and vogesite.

The nephelite syenite appearing over the southern portions of the map is continued southward in the San Carlos Mountains beyond the limits of the sheet for fifteen miles. The andesite touches it in a fairly even east-and-west line along the northern slopes of the Baril Range. At the contact the effects of quick chill in the andesite are seen. The rock at this point is aphanitic, although elsewhere uniformly coarse-grained, as is common in laccolithic masses. The nephelite syenite is older than the andesite. It is probable that the main mass of the San Carlos mountains was faulted up through the sedimentary series. The limestones and shales, in every part of the region which was visited, are stripped back from the nephelite syenite, and the actual contact between this rock and the sedimentary beds was not found.

There are many slight faults in the San José region. It is probable that some of the lesser stream courses have been directed by them. There is no break between the nephelite syenite and the andesite by faulting. The latter rock would seem to have come in on the edge of the nephelite syenite under

the limestone cover. It is also later than the exposures of diorite indicated on the map along the road leading to the Vegonia Mine, and in the stream-way a mile to the northeast of San José. The andesite has sent numerous small dikes into the diorite. This rock is met in three rounded bosses, enclosed by the andesite, and much weathered. It is often friable, and readily breaks up into a rusty brown soil like that which is furnished by the weathering of diabase.

On the eastern slope of the San Carlos range, and five miles from San José to the south, there is met a lava flow of basalt. The upper surface of the lava field, which is six miles long and a mile in width, is rough and vesicular. Much has been carried away from its surface by erosion. The body of the rock in the field is dense and aphanitic, rarely glassy. The basalt is black, at times with a slightly vitreous luster. It is of course much more recent than the massive nephelite syenite down whose flanks it flowed, and it is presumably younger than the diorite and the dike rocks. None of these were found cutting it. No cinder cone could be located in connection with it, if one ever existed.

The dikes, which are very numerous throughout the district, are of tinguaitite, camptonite, diabase and vogesite. They vary in width from half an inch to ten or twelve feet. They are usually found but slightly inclined away from the vertical.

The tinguaites are distinct in field habit from all the others. They are uniformly colored green. Two types are found among them — those which carry conspicuous phenocrysts of sanidine, and those which are aphanitic, and are characterized by showing no porphyritic developments in the hand specimen. No tinguaitite dikes were found cutting the nephelite syenite. Where they lie in the limestone they are seen to have had almost no effect upon it. The blue sedimentary rock continues up to the contact without being changed in any way. Two very large tinguaitite dikes are indicated on the map in the midst of the andesite. The longer of them runs for two and a half miles. It carries phenocrysts of sanidine, by which its even clear green color is mottled with white. Its outcrop

appears across the country in a line of huge rounded boulders which lie four or five feet above the andesite. A second dike, two miles long, cuts the first almost at a right angle. Numerous other dikes similar to these in field habit but smaller are given on the map. It is not known whether they are older than the basic series of dikes or not, since the members of the one are not found intersecting those of the other.

The basic dikes present considerable variety. They lie in the nephelite syenite and in the andesite and diorite. They are not found cutting across each other. None were met crossing the flow of basalt. The camptonite dikes are as common as those of diabase. The vogesite dikes are rare. The most interesting of these is found along Bretaña Creek half a mile southeast of Mt. Parreño. Its appearance in the field is like that of coarse diabase, but the feldspar proves to be orthoclase and the dark silicate appears under the microscope as green fibrous hornblende.

The order of succession among the igneous rocks of the San José region is, therefore, so far as known, beginning with the oldest, as follows:

1. Nephelite syenite and diorite.
2. Andesite.
3. Basalt, tinguaite, camptonite, diabase and vogesite.

VI. PETROGRAPHY

A. THE GRANITOID TYPES

The granitoid rocks of the San José district are nephelite syenite, exposed throughout the San Carlos Mountain range, and diorite. The former may at times be free from nephelite and then appears locally developed as true syenite. The diorite is a medium-grained rock which is only found as isolated patches underlying the andesite where the laccolithic mass has been deeply eroded. Dikes and offshoots of the andesite cut through the diorite, which antedates the formation of the laccolith. The diorite has diabasic affinities.

Nephelite syenite, the product of long-continued, deep-seated

cooling in magmas which are of medium percentages in silica, and contain large amounts of alumina and the alkalies, with low iron, lime and magnesia, has thus far been reported from but few localities in North America. It is found at Montreal, and in the county of Dungannon, Ontario, Canada; near the town of Litchfield, in Maine; on Salem Neck, and at Marblehead, in Massachusetts. It is met with at Red Hill, New Hampshire. A great dike-like mass occurs near Beemerville, New Jersey. Nephelite syenite has a large development near Magnet Cove, Arkansas, and the rock has likewise been described from Cripple Creek, Colorado, and from the trans-Pecos region of western Texas. Lawson's nephelite-pyroxene-malignite from the Rainy River district, Ontario, Canada, is a nearly related type. Similar occurrences of nephelite syenite and related rocks have been reported from the provinces of São Paulo, Rio de Janeiro, and Minas Geraes in Brazil by Derby.

The San José nephelite syenite is remarkable for its uniform character over large stretches. In the region studied it has not been split up into widely separated types such as are usually found where similar magmas have consolidated. Over nine tenths of the San José district it is a medium-grained, light or dark gray rock resembling granite. It is leucocratic and dull-looking by reason of the oily luster of the nephelite contained in it. The prisms and aggregates of the ferro-magnesian minerals are jet black, sharply outlined and in strong contrast with the lighter feldspars. Honey yellow, lozenge-shaped crystals of titanite are always found. It is only rarely that portions of the mass where the single crystals are locally developed in large size are observed, but individuals of orthoclase are sometimes an inch and a half in length; in other localities the basal sections of hornblende are three quarters of an inch in diameter, and rectangular masses of nephelite may be half as long again.

Black fine-grained basic segregations, like the knots in granite, are characteristic of certain limited tracts where they are so numerous as to give the nephelite syenite a mottled appearance. They are at times elliptical and again angular, and are found in all sizes up to five or six inches. They may be arranged in

bands with great regularity, so as to cause the rock to resemble gneiss.

The San José nephelite syenite carries a comprehensive series of the commoner rock-making minerals at nearly every locality which was visited. Feldspar, nephelite, amphibole and pyroxene are the usual essential components of the rock. Mica is rare as an accessory constituent, while titanite, magnetite and apatite are common. No sodalite, cancrinite, garnet, calcite, olivine, lavellite or wollastonite was found. The essential mineralogy lies between widely varied amounts of orthoclase and nephelite with soda augite and brown barkevikitic hornblende. Plagioclase is rarely present. Mica is never an important constituent.

Varieties occur where by the disappearance of nephelite the rock is a typical syenite. Again by the coming in of plagioclase it approaches litchfieldite. One variant from the normal type very low in orthoclase consisting principally of nephelite, hornblende and augite marks the passage over to the ijolites.

The San José nephelite syenite bears some resemblance to the Red Hill, New Hampshire, rock, but it does not carry sodalite. It differs from the Litchfield and Dungannon occurrences in its field habit, for it is never so coarse as these rocks are. Nor is it except in rare cases so poor in the dark silicates. It is unlike the Dungannon rock by reason of its large content of orthoclase, and as being so poor in mica. It closely parallels some of the more acid varieties from Magnet Cove, but its dark silicates, though sharply automorphic, are not developed in such perfection. Again the basic portions of the Mexican rock might almost pass for certain facies of the Beemerville nephelite syenite. The latter is commonly darker by reason of the dusty iron inclusions which crowd its feldspars. This character is never seen in the San José specimens. The rock was nowhere observed to grade into porphyritic varieties as would seem to be the case at Beemerville.

The nephelite syenite in the San José district has not suffered metamorphism. It never displays a schistose structure. The effects of mechanical strains are not shown in thin sections.

Inclusions of another rock were not observed. The Mexican nephelite syenite is a dense compact rock and its specific gravity is high. Descriptions of the four chief types in the San José district follow below.

1. *Nephelite Syenite.*

(a) *Baril Type.*

This variety of the nephelite syenite is exposed in the Baril range just east of the mountain of that name. In the hand specimen it is dark gray, with the colorless constituents in excess. It is fine-grained, and exhibits the usual non-porphyrific granitoid texture. Nephelite is present in small amounts only, and this variety of the rock lacks the characteristic greasy look which that mineral commonly imparts to it. White feldspar is a prime constituent, and with it are flashing black crystals of amphibole and pyroxene, and honey yellow grains of titanite.

Examination with the microscope shows that this variety of the nephelite syenite contains orthoclase, nephelite, hornblende, augite, titanite, magnetite, apatite and pyrite. Of these the first two make up perhaps 65 per cent. of the rock. The orthoclase, which is far more abundant than the nephelite, has, as a rule, a glassy habit. It is often much clouded over with inclusions, which are seen with high powers to be stubby prisms, brown and yellowish-green. They lie in the direction of the basal cleavage. A second cleavage at right angles to this is well developed. There is evidence that all the orthoclase crystals were not contemporaneous. Now and then partly automorphic individuals may be observed standing against others quite different from them in habit, owing to incipient kaolinization. Intergrowths between the feldspar and the nephelite are frequently seen, with irregular boundary lines between the two minerals.

The nephelite cannot readily be distinguished from the orthoclase except by its interference figure. It lacks the two systems of cleavage cracks, however, which show in the feldspar, and such cracks as do occur are very irregular. The mineral is clear and glassy. It is often filled with inclusions essentially like those in the orthoclase. (See Pl. IX, fig. 1.)

The hornblende crystals tend to be automorphic. Cross-sections are octagonal by the equal development of prism and pinacoidal faces, rather than six-sided, as is usual where (100) is suppressed. Terminal planes were not observed. The pleochroism in certain instances is *a* = seal brown, *b* = yellowish-green, *c* = light brown. Changing conditions in the composition of the magma are indicated by the dark green borders which usually surround the brown hornblendes. They are younger than the augite.

This mineral, which is much more abundant than the amphibole, is pleochroic, between olive green and dull green. Its surface is mottled by color changes in tones of green indicative of differences in chemical composition. The central portions of crystals are often tinged with violet. The short stubby prisms show poorly developed forms.

Apatite in six-sided prisms with perfect basal cleavage is common. The crystals are .4 mm. or less in length. They favor association with the dark silicates, as does also the magnetite. This mineral is in round grains .3 mm. across. Titanite is important in the rock. Its crystals are often 1.2 mm. in length. They are gray or nearly colorless. The Baril nephelite syenite contains numerous small grains of pyrite disseminated through it.

(*b*) *Arroyo Grande Type.*

The variety of nephelite syenite here described occurs midway between the Mesa Verde and Mt. Baril on the ridge overlooking the valley of the Arroyo Grande to the south. Its field habit is that of a very light gray rock in which the dark silicates make up only a very small portion of the whole. In the hand specimen the nephelite is very prominent, contrasting strongly by reason of its oily appearance with the kaolinized feldspar. With the aid of a pocket lens twinning may be observed on the orthoclase. Some titanite may also be seen occurring close beside the stray flecks of darker minerals. The texture is granitic with no porphyritic developments, and the rock is medium-grained.

Microscopic Characters. — Under the microscope the essential

minerals are seen to be orthoclase plagioclase and nephelite. Augite is rare and no hornblende was observed. Magnetite, titanite, apatite and epidote are the accessories. Measurements were made by using the micrometer eye-piece to determine the relative proportions in which these minerals are present. Somewhat over one hundred times the grain was recorded and the assignments to orthoclase and nephelite were constantly checked by interference figures. The result is given below.

Orthoclase	60
Plagioclase	5
Nephelite	25
Augite.....	1
Magnetite	8
Titanite	.7
Average grain.....	.36 mm.

The large amount of feldspar and nephelite in this rock with not more than 10 per cent. of ferromagnesian minerals is very striking. The large amount of magnetite present is also noteworthy. Hornblende was not observed.

The orthoclase occurs as a rule in simple crystals, less often in carlsbad twins, kaolinized and earthy looking. It presents at times rectangular boundaries. Cleavage cracks, most numerous parallel to the base, are unusually well developed, with a second set of cleavage cracks parallel to (010). The angle between the two cleavages when they appear on sections approximately parallel to (010) is 65° , or nearly that of the angle β for orthoclase.

The plagioclase, which marks by its presence the passage to the variety of nephelite syenite known as litchfieldite, is albite, in automorphic crystals, twinned in excessively fine lamellæ. Like the orthoclase it is often much altered.

The nephelite is older than the orthoclase as being, frequently, entirely surrounded by it. The crystals are 1 mm. in length and show a strong tendency toward an automorphic habit. Their substance is fresh, so that they may usually be separated from the feldspars by this character. The cleavage cracks, extinctions and figure on the basal section are the usual ones.

The soda augite which occurs so sparingly in this variety of the nephelite syenite is clear green in color. Its crystals are small and irregularly bounded. They are conspicuously pleochroic, apple green to brown. Titanite is found as a rule close beside the magnetite. Reaction rims between the latter mineral and feldspar are occasionally seen. Apatite is rare. Epidote is present in minute amounts.

(c) *Mesa Verde Type.*

This variety of the nephelite syenite occurs immediately to the east of the Mesa Verde. Seen in the hand specimen it is of a dark gray color from the large amounts of ferro-magnesian minerals contained in it. Clear, greasy nephelite may be recognized, and slightly weathered feldspar, apparently not so abundant, its cleavage surfaces having a vitreous luster. Clear yellow grains and crystals of titanite are present. The dark silicates occur as black masses which, except for an occasional six-sided crystal of hornblende, cannot be identified. The rock is fine-grained with a granitic texture.

Microscopic Description.— Under the microscope it is found that nephelite, orthoclase, hornblende and augite are the essential minerals. Magnetite, apatite and titanite are the accessories. By measurements with the micrometer eye-piece the mineralogical composition or mode of the rock was found to be as follows:

Nephelite	18
Orthoclase	12
Hornblende.....	40
Augite.....	23
Magnetite	2.7
Titanite.....	2
Apatite.....	1.2

The average grain is .2 mm. The structure is granitic with all the minerals more or less completely xenomorphic. From the above table the great prevalence of the dark silicates over the feldspar and nephelite together may at once be noted, as well as the excess of nephelite over orthoclase.

The orthoclase is in crystals inclining to a prismatic habit which average .4 mm. in diameter. They may at times be

slightly clouded over by the products of alteration. Occasional carlsbad twins are noted. This feldspar frequently surrounds large portions of the nephelite.

The substance of the nephelite is quite fresh. Its outlines tend to be rectangular. The cleavages parallel to the base and the prism are at times developed and the extinctions are parallel to these directions. Transparent microscopic crystals are present as inclusions in the nephelite, and surrounding it a secondary mineral, which is usually referred to cancrinite on account of its low index of refraction and high interference colors, is commonly developed.

Hornblende, the most abundant constituent of the rock, is the only mineral which has an automorphic habit, excepting the apatite. The unit prism and the pinacoidal planes, in the zone parallel to the c axis are well developed. The crystals are pleochroic from yellow to seal brown. The absorption is strong. Twins are not rare.

The augite in rude prisms and aggregates of grains is pale violet or greenish, with borders of deeper green from the coming in of the ægirite molecule. Intergrowths with amphibole are common. The augite encloses grains of titanite, and apatite needles.

Titanite occurs sporadically, in patches which are sometimes 1.5 mm. long. (See Pl. X, fig. 1.) The magnetite is in the usual grains with purple black luster. Apatite is very abundant in short stout crystals with its basal sections perfect hexagons charged with irregular dust inclusions. Some minute needles of epidote were observed.

The order of crystallization appears to have been as follows: First apatite, magnetite and titanite. Then hornblende and augite often enclosing the amphibole. The above minerals are frequently grouped together in such a manner, however, as to make it plain that their growth must have been in large measure simultaneous. After the dark silicates nephelite followed, and the feldspar came last.

(d) *Mesa Verde Type. Basic Facies.*

This variety of the nephelite syenite occurs closely associated with the Mesa Verde type in the same locality on the Baril

Range. It is a very dark gray, from the very large amounts of black ferro-magnesian minerals present. These are in prisms and grains surrounding masses of nephelite. No feldspar is apparent to the naked eye.

Microscopic Characters.—The microscope reveals, as the component minerals of this rock, apatite, titanite, magnetite, biotite, hornblende, augite, orthoclase and nephelite, in the order of their formation. The calculation of the mode by optical methods makes plain that only the last four play an important part in the rock. Hornblende is greatly in excess of all the other constituents put together. Orthoclase is very subordinate. Biotite is present in very small amounts. Its occurrence is significant. It is not found anywhere in the district except in the most basic forms of the nephelite syenite. The percentage composition is as follows:

Nephelite.....	13.2
Orthoclase.....	5.6
Hornblende.....	60.5
Augite.....	13.9
Biotite.....	2.2
Magnetite.....	0.4
Titanite.....	2.8
Apatite.....	1.4

The average grain is .16 mm. The texture is granitoid.

The mineral nephelite is younger than the orthoclase, with which it is in part intergrown. It appears in large areas, extinguishing at the same moment in which the feldspar and dark silicates are enclosed. It is very clear, except for inclusions of glass and fluid cavities. Its polarization tint is deeper than that of the feldspar. It is shown to be uniaxial and negative.

Orthoclase is largely interstitial between the crystals of amphibole. No plagioclase was observed.

The anhedral amphibole are gathered together to form large patches in the slide. Intergrowths with pyroxene are not found. The mineral is brown with pronounced pleochroism. *a*=light brown, *b*=seal brown, *c*=deep brown. The optic angle is large. The clinopinacoid is the plane of the optic axes. Extinction 21° . These properties are those which we should expect from barkevikitic hornblende.

The augite is light green. It differs from the usual varieties of this mineral in never showing borders indicative of an increase in the soda molecule. It is never tinged with violet. Rarely it may be seen as if grown out from the ends of the amphibole.

Brown biotite in thin lath-shaped plates .5 mm. in length is present as an accessory. It is notable for its inclusions, acicular transparent prisms of an undetermined mineral resembling rutile. They are usually inclined to the base at a sharp angle. Magnetite is rare, apatite and titanite common.

The specimen of the nephelite syenite (Baril type) analyzed by Dr. H. S. Washington, represents the average grain and mineralogy of the rock along the north end of the Baril range. Nephelite makes up about 18 per cent. of the whole. Augite, hornblende and biotite are all present. Apatite is conspicuous, and titanite may be easily seen in the hand specimen.

The results of analysis are given below, column I. Numbers II, III and IV are placed beside it for reference.

	I.	II.	III.	IV.
SiO ₂	58.40	59.01	60.39	51.90
Al ₂ O ₃	20.25	18.18	22.51	22.54
Fe ₂ O ₃	1.78	1.63	.42	4.03
FeO	2.41	3.65	2.26	3.15
MgO	.49	1.05	.13	1.97
CaO	3.11	2.40	.32	3.11
Na ₂ O	7.01	7.03	8.44	8.18
K ₂ O	5.39	5.34	4.77	4.72
H ₂ O ¹¹⁰	.27	.15		
H ₂ O ^{ign}	.57	.50	.57	.22
CO ₂	none		trace	
TiO ₂	.25	.81		
ZrO ₂	none	trace		
P ₂ O ₅	.20	trace		
SO ₃	.06			
Cl ₂	.02	.12		
S	none			
MnO	trace	.03	.08	
BaO	trace	.08		
CaO				
	100.21	99.98	99.89	99.82
	Less O for Cl ₂	.03		
		99.95		

- I. Nephelite syenite, Baril type, Tamaulipas, Mexico. H. S. Washington, anal.
 II. Nephelite syenite, Red Hill, N. H. W. F. Hillebrand, anal. W. S. Bayley, Bull. Geol. Soc. Amer., III, 250, 1892.
 III. Eleolite syenite, Litchfield, Me. L. G. Eakins, anal., Bull. Geol. Soc. Amer., III, 241, 1892.
 IV. Eleolite syenite, Brögger. Syenitpegmatitgänge, p. 33.

When the norm of this rock I is calculated in the standard salic and femic minerals the percentage composition is as follows :¹

Orthoclase.....	31.69	Magnetite.....	2.55
Albite.....	37.73	Diopside.....	6.62
Nephelite.....	11.64	Olivine.....	.55
Anorthite.....	7.78	Fem.....	9.72
Sal.....	88.84	H ₂ O.....	.84

The rock is therefore persalane, it belongs to order 6, rus-sare, it is domalkalic viezzenase and dosodic, viezzenose.

2. Diorite

The two principal areas in which diorite is exposed lie along the road leading to the Vegonia Mine, at a distance of about a mile from San José. The rock is also found in the gulch a mile due northwest of the town. It is usually deeply weathered and shows a rusty brown color in the field. The andesite is younger than the diorite and surrounds it completely, sending many small dikes into it. As before stated, the diorite probably lies below the andesite over much of the country where erosion has not revealed it.

When seen in the hand specimen this rock has the appearance of typical diorite. It has the granitoid texture. It is medium-grained, and dark gray in color. Plates of biotite are easily discernible through the rock. They are jet black, or brownish-black, and large enough to allow cleavage pieces to be scaled away. With the biotite small amounts of another dark silicate having no good cleavage may be identified. The microscope shows this to be a pyroxene. Taken together the darker constituents which are so prominent are not quite so

¹ "Quantitative Classification of Igneous Rocks," Cross, Iddings, Pirsson, Washington. The University of Chicago Press, Chicago, 1903.

abundant as the white or colorless feldspars. Carlsbad twins may occasionally be seen on these with the unaided eye. They are dull and show something of the oily luster which is characteristic of nephelite. Grains of titanite are scattered through the rock, and minute pieces of pyrite appear from time to time.

When examined with the microscope the rock is found to consist of plagioclase, augite, biotite, titanite, magnetite, apatite, pyrite and zircon, in the order of their relative abundance. There are no porphyritic developments. The outlines of the minerals (with the exception of apatite) are quite irregular, although the feldspars are commonly rectangular.

The plagioclase, as determined by the Michel-Levy methods is in two kinds, labradorite with the composition Ab_1, An_1 and a more acid andesine Ab_5An_3 . Its substance is fresh and glassy, though broken by many irregular cleavage cracks. The feldspars are twinned polysynthetically on the albite and pericline laws, with very fine twinning lamellæ. A zonal structure is occasionally observed.

The augite is in large irregular patches intergrown with biotite. This variety of pyroxene has a high extinction angle. It is light clear green and non-pleochroic. Twins may often be noted. The enclosures are apatite and magnetite. (See Pl. XII, fig. 2.)

The mica is a rich chestnut brown biotite, with strong absorption for rays perpendicular to the cleavage. Irregular masses of nearly colorless titanite are from time to time noted in the slide. Magnetite is abundant in large grains, now and then surrounded by rings of titanite. Rarely it shows a tendency to form rods growing out from the borders of the mica. The apatite prisms are well developed. The results of two analyses of this rock are given below, columns I and II. Numbers III and IV are placed beside it for reference.

	I.	II.	III.	IV.
SiO ₂	45.75	48.49	49.30	56.28
Al ₂ O ₃	18.51	18.99	22.46	14.23
Fe ₂ O ₃	6.55	9.59	{ 12.04	4.69
FeO.....	6.02	1.00		4.05
MnO				.16
MgO	5.06	5.05	2.14	6.37

CaO.....	11.85	10.78	9.30	7.94
Na ₂ O.....	3.41	3.47	3.01	2.98
K ₂ O.....	2.35	1.42	1.27	1.23
P ₂ O ₅	trace			.40
H ₂ O ¹¹⁰	.06	.10		
H ₂ O ^{ign}	.20	.55	.78	.93
	99.76	99.44	100.30	.17 Cl
				trace SO ₃
				.01 Li ₂ O
				100.28
			less O for Cl	.04
				100.24

I. Diorite, San José, Tamaulipas, Mexico. G. I. Finlay, anal.

II. Diorite, diabasic facies, San José, Tamaulipas, Mexico. G. I. Finlay, anal.

III. Diorite, Rosetown, near Tompkin's Cove, N. Y. J. F. Kemp, Amer. Jour. Sci., Oct., '95, 298.

IV. Diorite, Electric Peak, Yellowstone Nat. Park. J. E. Whitfield, anal. Monograph XXXII, Part II, U. S. Geol. Surv., p. 116.

The percentage compositions in standard minerals which give the norm for I and II are as follows :

I.		II.	
Orthoclase.....	8.34	Orthoclase	13.34
Albite.....	25.68	Albite	7.34
Anorthite.....	31.97	Anorthite	28.36
Nephelite.....	1.99	Nephelite	11.64
Diopside	16.85	Diopside.....	24.40
Olivine	3.36	Olivine.....	4.71
Magnetite.....	3.25	Magnetite	9.28
Hematite.....	7.30		99.07
	98.74		
H ₂ O	.65		
	99.39		

No. I is therefore salemose-limburgose, and No. II is salemose.

B. PORPHYRITIC TYPES

As may be seen in the geologic map, Plate VIII, the town of San José lies in the depression formed by the erosion of the central portions of a laccolithic mass of andesite. The rock is exposed continuously over twelve square miles of territory. Throughout the laccolith it varies but little from the even-

textured porphyritic habit which characterizes such intrusive masses. Denser textures show but rarely along the borders of the laccolith. The prevailing colors are light yellow and blue gray. Portions of the rock are locally richer in silica than the main mass, and show free quartz. All possible gradations exist between the normal andesite and the more siliceous dacite. Four types of these rocks will be described, as follows :

Andesite, San Narciso type ; Vegonia type.

Dacite, Florencia type ; Imogenia type.

1. *Andesite*

(a) *San Narciso Type*. — This variety of the andesite is largely developed to the north and west of San José.

In the field this rock presents an even gray ground-mass. It is leucocratic, with the darker crystals as scattered grains but sparingly developed, although basic segregations are more than usually common.

The feldspar, which is by far the most abundant mineral present, is recognized in the holocrystalline ground-mass by its bright cleavage faces. These show occasional twinning striations.

Under the microscope the structure is seen to be holocrystalline porphyritic, and plagioclase, orthoclase, augite, quartz, biotite, magnetite, titanite and zircon are determined as the constituent minerals.

The sections of plagioclase are lath-shaped pieces of labradorite, 1.2 mm. long by .5 mm. in breadth, appearing as porphyritic crystals in a very coarsely crystalline ground-mass which consists of orthoclase and quartz. (See Pl. XII, fig. 1.) The labradorite Ab_1An_1 appears in fresh crystals, largely free from the effects of weathering. These are twinned in fine lamellæ on the albite law, with many pericline lamellæ. When viewed between crossed nicols in the 45° position, one half of the crystal usually appears blue gray, the other yellow, indicating twinning on the carlsbad law. Zonal structure is very common. The outermost rims of the plagioclase crystals are often deeply changed by weathering. This material has the appearance of kaolinized orthoclase.

The crystals of orthoclase are shorter and stouter. They occur as carlsbad twins and are much altered and kaolinized.

The largest crystals of orthoclase do not attain a diameter greater than 1 mm. They are xenomorphic rude prisms which show marked pleochroism from light green to brownish-yellow.

The quartz is in xenomorphic rectangular and square pieces which give the characteristic uniaxial cross with one or two rings. They may be distinguished from the orthoclase squares by their glassy unweathered appearance. The quartz is seen to make up but a very small part of the whole rock.

Biotite, in small patches not above .2 mm. in length, is still rarer. Magnetite is found abundantly and small lozenge-shaped individuals of titanite are met in the slide. Some zircon is also present.

An analysis of the San Narciso type of the andesite is given below, as follows:

SiO ₂	62.31
Al ₂ O ₃	18.63
Fe ₂ O ₃	2.38
FeO.....	1.33
MgO.....	.60
CaO.....	5.91
Na ₂ O.....	4.97
K ₂ O.....	3.52
P ₂ O ₅	.07
H ₂ O ¹¹⁰	.16
H ₂ O ^{ign}	.07
	99.98

The calculation of the standard mineral composition or norm gives the following percentages:

Quartz.....	8.9	Diopside.....	4.1
Orthoclase.....	20.6	Wollastonite.....	2.5
Albite.....	41.9	Magnetite.....	3.5
Anorthite.....	18.1		10.1
Sal.....	89.24		

The rock is persalane and belongs to order V canadare. It is domalkalic and dosodic, laurvikose.

(b) Vegonia Type

This rock is exposed along the brook course 100 yards south of the Vegonia Mine. It is found as narrow dike-like stringers and larger masses irregularly intruded into the San Narciso type of andesite described above.

Megascopic Description.—When seen in the hand specimen it appears as an even-grained bluish-gray porphyritic rock with inconspicuous phenocrysts of feldspar and smaller grains of the dark silicates. The feldspars are at times a quarter of an inch long, but this is unusual. They average not more than one sixteenth of an inch in length. They often show the characteristic twinning of the plagioclases to the unaided eye. The darker silicates are by no means so abundant as the feldspars. Except for an occasional yellow crystal of titanite they are black. Taken altogether the phenocrysts make up half the rock.

Microscopic Description.—In thin sections the principal constituents of this andesite are found to be plagioclase, augite and hornblende, in conspicuous phenocrysts, with titanite, magnetite and apatite as accessories, in a fine-grained holocrystalline ground-mass consisting principally of feldspar, with lesser amounts of augite and magnetite in a second generation.

The plagioclase phenocrysts are in tabular crystals which are equidimensional. $M(010)$, $T(110)$ and $L(\bar{1}\bar{1}0)$ are conspicuously developed faces. Polysynthetic twinning occurs on the albite law and carlsbad twins are not uncommon. More rarely lamellæ which result from twinning on the pericline law have been noted. The lamellæ are generally broad, with intercalated fine bands. The extinction angles indicate labradorite. When a crystal cut at right angles to $M(010)$ which shows twinning on the albite law and carlsbad law at the same time can be found the concurrent extinction angles correspond to a labradorite with the composition Ab_1An_1 . The double refraction is high, often yellow of the first order. The labradorite crystals almost always show zonal structure. In habit they are usually microtinic and quite free from alteration products, but the core of a crystal has at times been shattered and afterwards sur-

rounded by a glassy zone of later growth. Inclusions of apatite, in very slender needles are common, and the whole substance of a labradorite crystal is often clouded with microscopic irregularly disseminated inclusions, probably pyroxene. Again iron-bearing solutions have stained the feldspar along cleavage cracks.

Augite, which is the most important of the dark silicates, is rather more abundant than hornblende. It is found in simple light green crystals bounded in the prism zone by the faces $m(110)$, $a(100)$ and $b(010)$, which favor association with the hornblende and magnetite. The crystals show an unusually good cleavage parallel to $a(100)$. Zonal structures are rarely observed. The extinction angle is 42° .

The hornblende is in very long slender prisms which are either rounded at the ends or terminated by two flattish faces. Occasionally they are twinned. They are of a dull brownish-green color and absorb the light strongly. Pleochroism is confined to shades of green.

Titanite, which appears sporadically in large irregular crystals, is the most notable of the accessory minerals present. The customary cleavage parallel to $l(110)$ is not well developed. Acutely rhombic sections are not common.

Magnetite, which but rarely shows crystal boundaries, is abundant in this andesite. Apatite is common among the older inclusions.

The ground-mass is a fine-grained aggregate of minute lath-shaped and irregular feldspars, microscopic magnetite grains and minute augite prisms of a second generation. The extinction angles on the feldspar microlites are low and point to oligoclase. Rude flow lines may at times be noted.

2. *Dacite*

(a) *Florencia Type*. — The rock here described exhibits every gradation towards the less siliceous andesite in the laccolithic mass. It is found in the hills immediately south of San José.

Macroscopic Description. — This type is very fine-grained. In the hand specimen the rock is of a pale brown color. It is

plainly porphyritic by reason of the larger crystals of feldspar, with flashing cleavage faces, which are just large enough to be recognized. A hand lens shows that their centers are somewhat weathered, while the outer rims are fresh. The dark minerals are not determinable in the hand specimen. They appear as minute black patches sparsely distributed through the ground-mass.

Microscopic Characters. — The study of thin sections reveals the presence of plagioclase, augite and quartz phenocrysts in a ground-mass, which is an intimate mixture of quartz and feldspar. Apatite, epidote, titanite and magnetite are the accessory minerals.

The plagioclase crystals are 1.2 mm. long, often in highly complex forms with only (010) and (110) distinguishable. The center is often deeply corroded, and secondary muscovite produced inside a clear outer rim. Many of the medium-sized individuals of the mineral are, however, quite glassy. Twinning according to the albite law with extremely fine lamellæ is very common, but many other lamellæ are often intercalated on the pericline law. The two halves of the crystals twinned at once on the albite and carlsbad laws show different interference colors in the 45° position. One is usually yellowish, the other blue gray. Symmetrical extinctions on the lamellæ of the two halves gives readings for an acid labradorite Ab_1An_1 .

The quartz phenocrysts are seldom above .1 mm. in diameter, but they are very common. Their substance is clear and glassy. It encloses needles of apatite, and only rarely shows, gas or liquid inclusions. The mineral is never automorphic. It has generally grown side by side with deeply kaolinized feldspar which comes in crystals much smaller than the labradorite phenocrysts. No twinning was observed on this second feldspar, which is identical with the feldspar of the ground-mass.

The pyroxene makes up a very small part of the rock. It is in irregular deep green twinned grains that are pleochroic yielding light and dark shades of green. Apatite in minute needles is a rare accessory, as is also epidote in short stubby grains. Titanite is present in irregular pieces not above .1 mm.

in diameter, and the grains of magnetite which are fairly abundant in the rock are still smaller. The ground-mass is a dense aggregate of pieces of quartz and kaolinized feldspars. These are on the average .05 mm. across and appear to be in nearly equal proportions.

(b) *Imogenia Type*.—The type here described occurs along Vegonia and Bretaña Creeks in the foothills of the Baril range.

Macroscopic Description.—In the field this rock when unweathered is grayish in color and shows a rough fracture. It is medium-grained and porphyritic in texture with a predominance of feldspar phenocrysts having bright cleavage faces as against the smaller proportions of the aphanitic ground-mass. Dark specks, shown by the microscope to be pyroxene, are scattered through the hand specimen.

Microscopic Characters.—The examination of this rock in thin sections shows that it is made up of plagioclase, orthoclase, quartz, augite, hornblende, biotite, magnetite, apatite and chlorite. Owing to the intimate mixture of quartz and feldspar in the ground-mass considerable difficulty is found in estimating the relative proportions between them optically. It is probable that there is an error of 5 per cent. in the subjoined table, which could not be guarded against. The mineral percentages by weight, as given in it, are however approximately accurate.

Plagioclase	32
Orthoclase.....	25
Quartz	17
Augite	16
Biotite.....	2.4
Magnetite	6.7
Hornblende }	.9
Apatite }	
Titanite }	
Chlorite }	
	100.0

The phenocrysts are of feldspar and quartz, augite, some biotite and the older generation of the magnetite. The accessory minerals make up perhaps 1 per cent. of the quartz-feldspar ground-mass.

The plagioclase of the older generation occurs in equidimensional crystals which often are 2 mm. in length. The albite, carlsbad and pericline laws are all represented in the twinning. The lamellæ on the albite law are excessively fine. The symmetrical extinctions given by them in the two halves of a carlsbad twin make possible the determination of the plagioclase as labradorite Ab_1An_1 . Zonal structure is very common. The substance of the plagioclase is often quite clear and glassy at the center, while the outer border of the crystal is commonly crowded with inclusions. Again the outer zone may be observed to extinguish at the same instant as the center of the crystal, while one or two intermediate shells have angles of extinction at variance with them. The outlines of the plagioclase individuals, as of all the other phenocrysts, are ragged and irregular.

Porphyritic crystals of orthoclase show twinning after the carlsbad law. Quartz is frequently intergrown with the orthoclase after the fashion of microgranite, where all the enclosed pieces of quartz extinguish at the same time. Perthitic intergrowths with plagioclase on a microscopic scale also occur. The orthoclase is always partly kaolinized.

The pyroxene does not usually show even an approach to good crystal outlines. Irregular grains of this mineral are common. It is light green, non-pleochroic, extinction 40° . Embayments produced in the crystals by the caustic action of the magma are frequently observed and the secondary minerals thus produced are magnetite and some little hornblende. By alteration the augite yields a dull green pleochroic fibrous chlorite.

Patches of a dull green slightly pleochroic hornblende, with an extinction of 15° , are rare, but may be as large as 2 mm. They are always ragged on all sides. Occasional poikilitic intergrowths between the hornblende and the pyroxene should be noted.

Patches of biotite as large as the hornblendes may be found at times. Secondary augite and magnetite grains occur around them as products of magmatic resorption.

The magnetite is usually surrounded by narrow rims of titanite, which may be secondary. The larger pieces of magnetite .4 mm. in diameter are to be taken as phenocrysts. Those of the second generation average .05 mm. They are in definite square sections of octahedra. Apatite needles are rare but titanite in dull grayish-yellow grains is often seen near the dark minerals. No pyrite was observed.

3. Basalt

Occurrence.—A lava flow of basalt may be traced on the eastern side of the San Carlos Mountains, extending back toward the range, along the course of the Arroyo Grande for four or five miles. The sheet is scoriaceous and vesicular on its upper surface, and appears to have issued from a fissure below the crags, at this point on the east of the Baril Range. The flow is perhaps half a mile in width. No volcanic cone was found on tracing it to its source.

Macroscopic Appearance.—In the hand specimen the rock is aphanitic and fine-grained. In color it is bluish-black. It breaks with a smooth splintery fracture. Blow holes show over its surface. The vesicular cavities are filled with calcite.

Microscopic Characters.—The rock is porphyritic with phenocrysts of feldspar and pyroxene. The augite was not observed in a second generation in the ground-mass, where lath-shaped feldspars, biotite and magnetite are the principal constituents.

The plagioclase phenocrysts are small, not above .4 mm. in diameter. The mineral occurs in poorly bounded thick tablets which are heavily charged with magnetite. The only inclusions are minute prisms of pyroxene. Wavy extinctions from center to margin are characteristic, but definite clearly marked zones of varying chemical composition are not observed. Twins on the albite law are common, but no other forms of twinning occur. Symmetrical extinction angles point toward labradorite. There is frequently a dense crowding together of magnetite grains for half a millimeter around a core of feldspar. Often the crystals of plagioclase have been acted upon by the magma until a mosaic of feldspar grains has resulted. Large, very

irregular and ragged pieces of augite are found associated with such evidences of disturbance. The mineral is of a bright green color with faint pleochroism to yellowish-green. The extinction is 40 degrees.

Biotite, plagioclase and magnetite form the ground-mass, the two first minerals being equally abundant. The feldspar is in small lath-shaped crystals often arranged in rude flow lines. They invariably show several minute twinning bands which give extinctions indicating a more acid feldspar than labradorite. They are believed to be andesine. They are automorphic and have invariably crystallized before the dark minerals.

The biotite never occurs in phenocrysts. It is always xenomorphic and interstitial between the feldspars. Small brown rectangular pieces sometimes attain a length of .1 mm. and from that sink to microscopic dimensions.

Magnetite, in grains and skeleton crystals, is scattered all through the rock and titanite occurs in notable amounts. An unresolvable glassy base makes up a small portion of the ground-mass.

The analysis and calculated standard mineral percentages of this rock are as follows :

SiO ₂	48.03	Orthoclase.....	11.68
Al ₂ O ₃	20.98	Albite.....	24.10
Fe ₂ O ₃	7.06	Anorthite.....	36.70
FeO	4.51	Nephelite.....	1.99
MgO.....	4.43	Diopside.....	8.37
CaO.....	9.54	Olivine.....	6.25
Na ₂ O.....	3.28	Magnetite.....	10.21
K ₂ O	1.99	H ₂ O.....	.61
H ₂ O ¹¹⁰	.21		99.91
H ₂ O ^{ign}	.40		
	100.49		

G. I. Finlay, anal. The rock therefore belongs with order 5 of class II, in rang 4 and grad 3, hessose.

C. DIKE ROCKS

Over fifty separate dikes were observed in the region immediately about San José. They fall into two groups, the

more acid, tinguaite and offshoots from the andesite mass, and the basic series. They tend to assume two general directions in their distribution. Most of them strike nearly north and south. The great tinguaite dike which extends from Mt. Anacuas to the south of Mt. Parreño is an exception to this rule. A second set of dikes follows the east-and-west direction at right angles to the first series. The great tinguaite dike which belongs with these, running from the foot of Mt. Armadillos to the slopes of Mt. Parreño, has been faulted aside for 150 yards near the town of San José.

The tinguaite dikes fall into two divisions :

1. The more acid types which in the field are easily recognized by their abundant porphyritic crystals of orthoclase.
2. Those which are aphanitic and are characterized microscopically by the presence of analcite.

The tinguaite cuts the limestones and the andesites, but they were not found in the nephelite syenite. The other dikes are all of them presumably later, and they are believed to represent several periods of eruption. They do not cut across the tinguaite in the region examined. In only one instance was a dike found intersecting another. The basic dikes are seen cutting through the nephelite syenite as well as the other rocks of the district. Good exposures occur along the roads leading from San José to the Santa Helena, San Narciso and Vegonia mines. These dike rocks are all of them aphanitic and black-looking, sometimes slightly inclined to bluish, brownish or grayish. The following basic types are included in the descriptions :

Camptonite.

Vogesite.

Limburgite.

The tinguaite shows a uniform field habit, with the characteristic green color due to microscopic prisms of ægirite. They are more numerous than any other of the San José dikes. They may be without phenocrysts, and again are notably porphyritic by reason of the orthoclase crystals which they contain. They are found not only in the andesite, and cutting the limestone, but far to the northwest of the San Carlos Mountains as well,

and for many miles along the eastern and western flanks of the range. In some cases single dikes may be traced for one and a half or two miles with a width of ten feet.

1. *Tinguaite*

(a) *Santa Rita Type*. — The variety of the tinguaite here described is met in a dike between the Mesa Verde and Mt. Parreño near the pass which the Santa Rita trail takes on leaving the San José valley.

In the hand specimen the rock is noticeably darker than the other tinguaite of the district. It is a dense compact rock having a deep green aphanitic ground-mass in which tablets of sanidine often 2 cm. in length occur prominently as phenocrysts. Without a hand lens it is difficult to distinguish the larger crystals of ægirite in the dense aggregate made up of the minute individuals of that mineral. Amygdaloidal cavities occur which contain tiny shreds and patches of biotite, magnetite grains and the earthy aggregates that have resulted from the weathering of the zeolites.

Microscopic Description. — Besides the sanidine and ægirite the microscope shows that nephelite, plagioclase, hornblende and analcite are present.

The larger phenocrysts of feldspar are in sharply automorphic carlsbad twins bounded by (110) and (100). They attain a maximum length of 3.5 mm. and are one quarter as broad. (See Pl. X, fig. 2.) They contain many inclusions, minute prisms of ægirite zonally arranged with their long axes parallel to the walls of their host, and bundles of microscopic brightly polarizing needles having a high index of refraction. The feldspar crystals show peculiar effects of weathering and secondary replacement. Good cleavage cracks appear rarely. Now and then kaolinized cores remain, but nine tenths of their substance is usually of secondary origin, largely orthoclase feldspar, plagioclase and analcite. The cores of the original crystals have been eaten out and in the central portions analcite is now found. (See Pl. XI, fig. 2.) This mineral is isotropic, and it gives no interference figure. It has two sets of cleavage cracks at right

angles to each other. It may extend out from the center as far as the original boundaries of the feldspar or it may be surrounded by a zone of feldspar crystallites packed in together like the skeleton crystal needles in spherulitic bodies. These bundles of needles are intergrown with definite initial forms of ægirite. The microscopic growths of this mineral resemble the occurrence of pyroxene in the Arran pitchstone. Now and then lines of grains of ægirite run out toward the center. Again a corroded space in the original orthoclase has been filled by bundles of plagioclase needles or by analcite and clear secondary feldspar, the latter untwinned and surrounded by the zeolite. These circumstances are favorable for deciding as to the relative indices of refraction by the Becke method. The lines of light migrate outwardly from the analcite into the feldspar on either side. When observed with high powers the zeolitic substance is clear and glassy while the secondary feldspar associated with it is distinctly granular.

Two other generations of feldspars besides the large phenocrysts are well marked. Those belonging to the second period are comparatively fresh. They appear as six-sided individuals .3 mm. in length. Finally, feldspar appears as an aggregate of orthoclase grains and minute lath-shaped crystals with soda pyroxene in the ground-mass. Here the emerald green prisms, arranged in felty aggregates, are noticeably shorter and stouter than is usual in the ground-mass of other San José tinguaites.

They are not frayed at the ends and their edges are firm and sharp. They have not been noticeably crowded together by the growth of the large feldspar phenocrysts, but have been forced to grow with their long axes parallel to the latter, when they lie near them. The ægirites at times cluster thickly about a large grain of magnetite.

Individuals of the pyroxene three times as large as those in the ground-mass represent an older generation. Very rarely phenocrysts of chestnut brown hornblende, pleochroic in shades of brown .1 mm. in diameter, twinned parallel to (100) are observed as nuclei for clusters of ægirite. The biotite of the rock, in minute patches, is rare and of secondary origin. Magnetite grains do occur but not commonly.

(b) *Iman Type*.—The variety of the tinguaitite to be described under this name is found in a dike four feet wide which is exposed for fifty feet, extending in a north-and-south direction, immediately to the west of the Piedra Iman.

Macroscopic Characters.—In the field the rock has a light brown color. Its texture is porphyritic with many very small white tabular crystals of feldspar appearing as the only discernible phenocrysts in a dense aphanitic ground-mass.

Microscopic Characteristics.—Under the microscope it is found to contain, besides prevailing orthoclase and some little nephelinite, smaller amounts of ægirite, magnetite and limonite. The ground-mass shows a marked fluidal arrangement.

The orthoclase appears in two distinct forms as the result of as many periods of crystallization. The phenocrysts are nearly always very long and narrow tablets twinned on the carlsbad law, but rectangular more isometric crystals are now and then found. The feldspar is always much kaolinized. The basal and clinopinacoidal cleavages show distinctly. The orthoclase laths in the ground-mass are very narrow, and hardly .2 mm. long.

The nephelinite presents clear surfaces of low relief not broken by cleavage cracks. It is found in rudely hexagonal phenocrysts which give a uniaxial figure. (See Pl. XI, fig. 1.)

The ground-mass contains, besides the feldspar, rods of ægirite, small amounts of nephelinite, ragged pieces of magnetite, and secondary limonite. The ægirites are broader and less regular than the feldspars. By weathering they take on a fibrous appearance and tend to lose their bright green colors. The nephelinite is fresh and clear. It gives rise to the deep blue-gray colors with crossed nicols where it is seen in the interstices of the ground-mass.

2. *Analcite Tinguaitite*

(a) *Mt. Armadillos Type*.—The variety of the tinguaitite here described is found in the important dike which runs as a great wall across the country from the western slope of Mt. Armadillos to the foot of Mt. Parreño. It is so much more resistant

than the andesite which surrounds it that it is always left in relief by the differential effects of weathering. It is of a light green color in the field. Its texture is porphyritic, with glassy sanidine crystals in a dense homogeneous ground-mass, as the chief phenocrysts. Small specks of biotite may be seen in the hand specimen. The rock has a peculiar greasy luster.

Microscopic Characters. — Under the microscope this tinguaitite is found to have the pilitic texture where minute ægirite needles, amounting to 50 per cent. of the whole, make up a dense felty aggregate, in which sanidine, analcite, and, rarely, porphyritic crystals of pyroxene and biotite patches are found.

The analcite crystals are in small squares less than .1 mm. in diameter, and in polygonal and rectangular sections. They are colorless and appear so abundantly as to cause darkness by crossed nicols over most of the field.

The sanidine phenocrysts are clear and colorless. They give blue-gray interference colors. Carlsbad twins may often be noted. The sanidines have no good cleavage cracks, but they exhibit the usual crude parting parallel to (100).

A few ægirite needles of an older generation occur. This mineral in the ground-mass is faint green or almost colorless. The individuals are very small, usually only .1 mm. in length. They are sharply bounded, and appear packed in together with tiny feldspars to form a very dense aggregate. The small crystals of sanidine associated with them are all automorphic, and many of them show twinning. Traces of magnetite, rare patches of biotite and areas of secondary limonite are to be noted.

(b) *Corona Type.* — The type here described could not be found in place. The dike from which the boulder, collected in the bed of Breña Creek, came, was doubtless up near the waters of that stream against the Baril Range.

Megascopic Description. — The hand specimen shows a slate-colored rock, having a felsitic texture. Phenocrysts of greasy-looking nephelite and crystals of sanidine are visible to the unaided eye, and with a pocket lens the carlsbad twinning may be noted on the feldspar. A dark silicate sparingly disseminated through the rock proves to be ægirine-augite.

Microscopic Characteristics.—Under the microscope two textures are observed. Besides the usually strictly porphyritic phase of the rock, a fine-grained variety occurs in which all the crystalline masses are of approximately equal size. Squares and hexagonal sections of nephelite, grains of ægirite and titanite and carlsbad twins of glassy sanidine are the constituents, with accessory minute needles of apatite. These are the commoner minerals which make up the rock. Analcite and rare augite should be mentioned to complete the list.

The orthoclase is in extremely long narrow carlsbad twins (1.2 mm. by .15 mm.), resembling the smaller ones common in the normal trachyte ground-mass, or again in thick tablets, colorless and glassy, but dusted over with extremely minute rod-like inclusions which tend to lie parallel to the prism directions.

Nephelite, in six-sided and rectangular sections .6 mm. by .8 mm., is very common. This mineral gives at times a satisfactory uniaxial interference figure. It is often white, inclining to buff color. Ægirite inclusions are observed in it with zonal arrangement. Minute inclusions of the same pyroxene, in sharp lines, produce an effect of ruling which is much like the appearance of definite cleavage cracks. The nephelite is altered but little. Analcite, chiefly, results by weathering.

Augite is the usual pyroxene. Three generations in all of the mineral are observed. It occurs in short stout prisms 1.2 mm. by .5 mm. as phenocrysts. The extinction angle is nearly 45° . Poikilitic intergrowths of the augite, tinged with a violet color, and included emerald green patches of ægirite are very common. Zonal structures are seen at times in such crystals, the several shells having unlike orientation optically. Much apatite and some magnetite are associated with the larger individuals.

Titanite, showing no unusual characteristics, is found in bladed crystals 1.2 mm. long. Patches of biotite were noted, but the mineral is present only in extremely small amounts. Grains of magnetite are scattered through the rock and pyrite is sometimes present.

The ground-mass is very rich in laths of orthoclase feldspar. These and ægirite rods make up almost the whole of it.

Two analyses of the analcite tinguaita are given below.

	I.	II.
SiO ₂	52.83	49.42
TiO ₂	.16	
Al ₂ O ₃	20.70	22.99
Fe ₂ O ₃	2.84	2.70
FeO	1.19	1.89
MgO	.41	.45
CaO	1.00	2.59
Na ₂ O	9.94	9.63
K ₂ O	4.87	4.21
H ₂ O ¹¹⁰	.37	
H ₂ O ^{ign}	5.28	5.73
P ₂ O ₅	.03	
Cl	.06	
	99.62	99.99

I. Analcite tinguaita, San José, Tamaulipas, Mexico. H. S. Washington, anal.

II. Analcite tinguaita, San José, Tamaulipas, Mexico. G. I. Finlay, anal.

The calculation of I results as follows in percentage composition by standard minerals :

Orthoclase.....	28.9	Acmite.....	4.2
Albite.....	25.7	Diopside.....	4.2
Nephelite.....	29.0	Magnetite.....	2.1
Sal.....	83.6	Fem.....	10.5

The rock, therefore, belongs to order 6 russare of the persalanes. It is peralkalic miaskase and dosodic miaskose.

Number II gives the following mineral percentages for its norm :

Orthoclase.....	25.02	Magnetite.....	3.94
Albite.....	19.91	Diopside.....	4.86
Anothite.....	7.23	Fem.....	8.80
	52.16		
Nephelite.....	33.23		
Sal.....	85.39		

It is tasmanare order 7 of the persalanes. It is peralkalic laugenase and dosodic laugenose.

3. *Camptonite*

(a) *San Carlos Type*. — Numerous small dikes of this rock are found in the more basic portions of the nephelite syenite

mass. They are often less than an inch in width. To the unaided eye they present the appearance of dense basalt except as being porphyritic by reason of the shining black crystals of hornblende which they contain. The contacts with the enclosing nephelite syenite are very sharp. Even in the smallest dikes near the walls little included pieces of the nephelite rock may at times be found. These dikes are almost always quite fresh, but cavities filled with secondary minerals are met.

Microscopic Description.— Under the microscope this variety of the camptonite appears as a holocrystalline porphyritic rock with marked fluidal arrangement. Hornblende in two generations makes up over four fifths of the whole. Augite is present in phenocrysts, perhaps five per cent. of the total rock. Feldspar in minute areas is packed away in the interstices of the ground-mass. Apatite and magnetite are prominent. The ground-mass shows pronounced flow structure. The grain is much finer near the contact with the enclosing nephelite syenite.

The phenocrysts are chiefly brown basaltic hornblende, with no noticeable effects of alteration. The basal sections of this mineral are sometimes .5 mm. in diameter. They are of the usual six-sided forms and generally give indications of zonal structure. Long prismatic individuals are often dull green at the center with an outer rim of the brown hornblende. In other crystals this order is reversed. The angle of extinction is low, not over 9° . Pleochroism is confined to shades of brown. Twins are common. Apatite and magnetite are the usual included minerals and rims of the latter due to magmatic resorption are sometimes seen. (See Pl. XII, fig. 2.)

Phenocrysts of augite are much rarer. This mineral is violet gray in color and scarcely pleochroic. Its crystal outlines are never perfect for a surrounding rim of serpentinitic alteration products is invariably present. The smaller augites of the ground-mass are entirely altered to serpentine. Almost the whole of the ground-mass however is made up of hornblende and interstitial feldspar. Magnetite grains at times .15 mm. across and large perfect crystals of apatite occur sporadically.

The hornblende prisms of the younger generation average .07 mm. in length by .01 mm. in breadth. They show the same colors and pleochroism as do the larger hornblendes. The pieces of feldspar packed in between the hornblendes are very minute, seldom above .02 mm. in length. No twinning could be observed. The feldspar in thin sections is very clear and fresh. Irregular pieces of magnetite, often nearly as large as the augites, are surrounded as the pyroxene is by serpentinic rims. The perfect crystals of apatite .07 mm. across on the basal section are notable for the inclusions which they contain of microscopic hornblendes, zonally arranged.

(*b*) *Casa Grande Type*. — The variety of camptonite here described is met in a three-foot dike on the road leading to San Carlos just as one leaves San José.

Microscopic Characters. — Seen in the hand specimen the rock is black and very fine-grained. Only a few shining prisms may be made out in the dense aphanitic ground-mass.

Microscopic Appearance. — Under the microscope the rock shows a holocrystalline porphyritic texture. The phenocrysts are of hornblende and augite, embedded in a ground-mass made up of little feldspars, hornblende, augite, magnetite and apatite. Calcite and analcite are secondary products.

The augites of the older generation are by far the most abundant phenocrysts. Eight-sided sections are developed, with very perfect crystal boundaries, which are defined by the usual faces $m(110)$, $a(100)$ and $b(010)$. The pyroxene prisms are usually half as broad as they are long. They take all possible orientations. The color varies considerably. Violet gray prevails but light shades of green are often observed. Some crystals are nearly colorless. The mineral is pleochroic between gray and shades of green. A zonal structure is usually developed with green or violet cores, and a colorless outer shell. Inclusions of apatite and magnetite are in linear arrangement parallel with the crystallographic faces. An exterior shell of magnetite grains has often been added by magmatic resorption, or where no secondary magnetite has formed the crystal edges are usually frayed out. The extinction angle is nearly 45° .

Intergrowths with hornblende have been observed but they are rare. Sections approximately parallel with (001) show the emergence of an optic axis at one side of the field.

Phenocrysts of hornblende are associated with the porphyritic crystals of augite. This mineral is in eight-sided sections, .9 mm. by .6 mm., which have $m(110)$, $b(010)$ and $a(100)$, in the prism zone, very sharply developed. The pleochroism is strong, a = pale yellowish-brown, b = deep earthy brown, c = light brown. The crystals are often composed of two or more shells of varying chemical composition, the inner core being the darker. The whole individual may be surrounded by a thin rim of grains of magnetite, although embayments resulting from magmatic resorption are rare. The extinction angle is low, 4° . Alteration at the center of the larger crystals leads to the formation of calcite.

Both the above minerals occur in a second generation in the ground-mass. The hornblende is in long and very narrow clear brown blades which fray out at the ends. They are noticeably fibrous. Their extinction angle is low. They attain a maximum size of .7 mm. by .03 mm. but usually they are but half as large. They make up about 10 per cent. of the rock. Augite occurs in the ground-mass in rough grains and stubby prisms .2 mm. by .05 mm., gray or nearly colorless. It is perhaps twice as abundant in the ground-mass as is the hornblende. Much magnetite is associated with it and square sections of this mineral are very common. Needles of apatite which are large and perfect are found near the augite.

The feldspar of the ground-mass is commonly xenomorphic. It seems to have been the last mineral to crystallize out of the magma. Occasionally well-defined minute plagioclase individuals are found which are evidently secondary. Their extinction angle is uniformly one or two degrees, indicating oligoclase.

Alteration products are very common in this rock. Calcite is everywhere disseminated through it in granular masses. The zeolitic minerals have frequently formed in small cavities, and at the center analcite is generally found. In this rock the mineral is colorless, with very few cleavage cracks. It is com-

pletely isotropic. It clouds over when the section is heated to redness, and gelatinizes with acid.

An analysis of the above rock gave the following percentages :

SiO ₂	42.49	The calculated norm of the	
Al ₂ O ₃	17.68	rock is given below.	
Fe ₂ O ₃	5.12	Anorthite.....	20.02
FeO	5.90	Leucite	13.95
MgO	5.28	Nephelite.....	19.60
CaO	15.81	Diopside.....	14.84
Na ₂ O	4.29	Olivine.....	9.14
K ₂ O	2.97	Ackermanite	14.55
H ₂ O	.38	Magnetite	7.42
	99.92		99.52

It belongs with order 8 of class III and falls in rang 3 and in grad 4, covose.

(c) *Rincon Type*. — The variety of the camptonite here described occurs in narrow dikes at various points to the east and southeast of San José.

Macroscopic Appearance. — In texture this rock is holocrystalline porphyritic with phenocrysts of plagioclase in a ground-mass consisting of feldspar, augite, hornblende and magnetite. Chlorite, muscovite, calcite and epidote are the common alteration products. The plagioclase is in large complex individuals twinned polysynthetically with many fine lamellæ, the crystals being often 1 mm. on either dimension. They afford favorable cases for the estimation of the basicity when a section cut at a right angle to the albite lamellæ may be shown to represent the two halves of a carlsbad twin as well. Such readings indicate anorthite, and the extinction angles on many albite lamellæ are high enough to give confirmation to this determination. The phenocrysts of plagioclase often show an inner core surrounded by a rim which has a different orientation optically, or, more rarely, zonal structure, consisting of many shells, is observed. Colorless mica, in patches 1 mm. long has resulted where the feldspar is weathered, and with it more or less chlorite is associated as having come from the same source.

The small lath-shaped plagioclases in the ground-mass, which are fresh and glassy, have low extinction angles, near 10° . They are therefore much more acid than the feldspars of the first generation. They are often twinned in three or four fine lamellæ. They are automorphic and by their distribution they cause the rock, at times, to approximate the diabasic texture. Altogether plagioclase makes up about 50 per cent. of the whole.

The augite, which was once the most abundant dark silicate throughout the ground-mass, is now nearly all changed over to chlorite. This mineral is faintly pleochroic from yellowish-green to green, and shows but slight effects of double refraction.

The hornblende of the ground-mass has a rich brown color. It occurs as xenomorphic grains and patches which have a low extinction angle. The interference colors are high. The pleochroism is inconsiderable, various shades of brown prevailing. Square pieces and irregular grains of magnetite make up about 5 per cent. of the rock. Calcite is very generally present as an alteration product. Minute needles which give high interference colors are epidote.

4. *Vogesite*

The rock to be described under this name occurs as a four and a half foot dike in the andesite along Bretaña Creek. It is aphanitic and almost black. It carries no phenocrysts discernible to the unaided eye.

Microscopic Characters.—Under the microscope it is found to be holocrystalline and to contain hornblende, augite and orthoclase, with magnetite, some plagioclase and titanite and minute foils of biotite. There are no well-marked porphyritic developments. The orthoclase, which was the last mineral to take crystalline form, encloses all the other constituents. It is without good crystallographic boundaries. Carlsbad twins may occasionally be noted.

The augite crystals are light buff-colored, xenomorphic, .25 mm. in length by .1 mm. in width, and not pleochroic.

The extinction angle is large, nearly 45° . Zonal structures are developed. The pyroxenes are often surrounded by prisms of monoclinic amphibole.

The hornblende makes up by far the largest portion of the rock. The individuals of the mineral are in fibrous blades poorly defined by crystal faces in the prism zone. They attain a maximum extension of .4 mm. and are eight or nine times as long as they are broad. Their color is dull green. By pleochroism changes to dull brown are produced. The cores of the hornblende crystals are at times different in composition from the outer rims. Twins are rare. Extinction 20° .

Some plagioclase, evidently of secondary origin, occurs as minute patches in the orthoclase ground. Biotite foils .1 mm. or less in diameter are now and again associated with the clusters of hornblende crystals. Titanite is disseminated through the rock in microscopic lozenge-shaped individuals. The larger magnetite grains may be surrounded by rims of this mineral.

5. *Limburgite*

The rock to be described under this name is found in a dike on the western flanks of the San Carlos Mountains five miles south from San José. The hand specimen shows it to be a lusterless black aphanitic rock.

Microscopic Characters.—Under the microscope a well-developed porphyritic texture with a fine-grained holocrystalline ground-mass is at once apparent. The phenocrysts are augite and olivine. Hornblende, augite and plagioclase make up the ground-mass.

The augite phenocrysts as a rule are sharply bounded individuals which attain a length of .6 mm. or less. Their color is violet gray and they are slightly pleochroic. A zonal structure with many concentric shells may usually be noted, and with this the hour-glass structure is developed. Inclusions of magnetite grains are arranged zonally. At times there is evidence of magmatic resorption, and around the main crystal a rim of secondary augite is developed. Again the center is corroded while the outer zone is clear. Twins may often be

noted with (100) as the composition face. The twinning is occasionally repeated in the same individual.

Olivine is the only other phenocryst. (See Pl. XIII, fig. 1.) Several crystals of this mineral often grow together. They almost always show corroded outlines. The inclusions are augite and magnetite.

The chief mineral of the ground-mass is a pale brown hornblende in short stubby prisms of microscopic proportions .05 mm. by .02 mm. These are slightly pleochroic. The basal sections are eight-sided by the development of the prism and pinacoid.

The many small augites of a younger generation are by no means so numerous. They may be easily distinguished from the hornblendes by their buff color. Interstitial feldspar is found all through the ground-mass in pieces which are too small to give a clue as to their characteristics. Grains of magnetite are everywhere present and secondary analcite should be noted.

TABLE I

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO ₂	58.40	42.49	62.31	45.75	48.03	48.49	52.83	49.42
TiO ₂	.25						.16	
Al ₂ O ₃	20.25	17.68	18.63	18.51	20.98	18.99	20.70	22.99
Fe ₂ O ₃	1.78	5.12	2.38	6.55	7.06	9.59	2.84	2.70
FeO	2.41	5.90	1.33	6.02	4.51	1.00	1.89	1.89
MgO	.49	5.28	.60	5.06	4.43	5.05	.41	.45
CaO	3.11	15.81	5.91?	11.85	9.54	10.78	1.00	2.59
Na ₂ O	7.01	4.29	4.97	3.41	3.28	3.47	9.94	9.63
K ₂ O	5.39	2.97	3.52	2.35	1.99	1.42	4.87	4.21
P ₂ O ₅	.20		.07	tr.			.03	
H ₂ O ¹¹⁰	.27	.38	.16	.06	.21	.10	.37	.38
H ₂ O ^{ign}	.57		.07	.20	.40	.55	5.28	5.73
	100.13	99.92	99.95	99.76	100.49	99.44	99.62	99.99

I. Nepheline syenite. H. S. Washington, analyst.

II. Camptonite. G. I. Finlay, analyst.

III. Andesite. G. I. Finlay, analyst.

IV. Diorite. G. I. Finlay, analyst.

V. Basalt. G. I. Finlay, analyst.

VI. Diorite. Diobasic facies. G. I. Finlay, analyst.

VII. Analcite tinguaita. H. S. Washington, analyst.

VIII. Analcite tinguaita. G. I. Finlay, analyst.

TABLE II

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO ₂	.973	.708	1.038	.762	.800	.808	.880	.823
Al ₂ O ₃	.198	.173	.182	.181	.206	.186	.203	.226
Fe ₂ O ₃	.011	.032	.015	.040	.044	.060	.018	.017
Fe ₂ O	.033	.082	.018	.083	.062	.014	.017	.027
MgO	.012	.132	.015	.126	.110	.126	.010	.011
CaO	.056	.282	.105	.211	.170	.193	.018	.047
Na ₂ O	.113	.069	.080	.055	.053	.056	.160	.155
K ₂ O	.057	.032	.037	.024	.021	.015	.052	.045

TABLE III

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Na ₂ O	1.98	2.15	2.16	2.29	2.52	3.73	.307	3.44
K ₂ O								
FeO	3.00	2.56	1.20	2.07	1.40	.233	.944	1.58
Fe ₂ O ₃								
Na ₂ O+K ₂ O	.174	.142	.112	.103	.092	.087	.240	.243
SiO ₂								
Na ₂ O	.116	.097	.077	.072	.066	.069	.181	.183
SiO ₂								

VII. CHEMICAL RELATIONS OF THE SAN JOSÉ ROCKS

In Table I, page 292, are given the results of the eight analyses which have been made of the San José rocks. The percentage composition by weight is indicated here for each oxide. In Table II the molecular amounts of the oxides have been obtained by dividing the percentage composition for each constituent by the corresponding molecular weights. In Table III the ratios for certain of the oxides when compared with other constituents in terms of their molecular amounts in every case, are stated.

It will be noted, when the analyses which embrace nearly all the rock-types of the district are examined, that the range in silica between the most acid member, andesite, and the most basic, camptonite, is not large. The nephelite syenite is more acid than is usual with such rocks, and the tinguaite is more basic. The type andesite is also poorer in silica than the average of many andesites. Alumina is high in every analysis.

Fe_2O_3 and FeO vary between wide ranges. The rocks are all comparatively high in lime, some of them, as the diorite and camptonite, abnormally so. They are high in the alkalis, and in every one soda is two or three times as great as potash.

High soda and alumina, with low silica, makes necessary the formation of orthoclase and nephelite, with ægirite in the tinguaïtes, and light green soda augite in the nephelite syenites. Here also the dark brown hornblende, rich in iron, which appears in the more basic varieties, is edged with green by relative increase in the amount of soda present in the later stages of crystallization from the rock magma. Magnesia is very low in the nephelite syenites and tinguaïtes. Biotite is almost entirely lacking in these rocks. It only enters into the most basic of the nephelite syenites. The mineral is, however, present in the diorites where MgO is relatively high.

The character of the augite in all the rocks of the district is very uniform. It is a light green variety, poor in iron and magnesia and rich in soda. Its appearance and optical properties are much the same in the normal nephelite syenite, in the andesite, in the diorite, and even in the camptonites.

As stated above, the rocks of the San José district, so far as the proofs are at hand, fall into three divisions, from the earliest to the most recent.

1. Nephelite syenite and diorite.
2. Andesite and dacite.
3. Basalt, tinguaïte, camptonite, vogesite and limburgite.

There are represented effusive and deep-seated rocks which vary widely in chemical composition. The analyses, however, when placed side by side in the order in which they have been printed are seen to follow in a definite sequence. They are not in a "series," according to Brögger's use of the term. They are related after the manner of his "faciessuite." The tinguaïtes when examined with the others are found to present striking differences toward them. It is possible that they are part of a tinguaïte "series." The ratios between the sum of the alkalis and silica, and between soda and silica are nearly the same in the two tinguaïtes, but the alkalis function together in

both, as do also the ferrous and ferric molecules, and in the same sense.

The ratios for all the other rocks of the region, so far as analyses are available, are found to vary in a definite manner.

They tend to fix themselves as multiplies of $\frac{1}{4}$ for $\frac{\text{Na}_2\text{O}}{\text{K}_2\text{O}}$ and

$\frac{\text{FeO}}{\text{Fe}_2\text{O}_3}$, and the variation is never more than .10, nor usually

so large. $\frac{\text{Na}_2\text{O}}{\text{K}_2\text{O}}$ is constantly on the increase from left to right,

between 1.98 and 3.73. $\frac{\text{FeO}}{\text{Fe}_2\text{O}_3}$ varies in the opposite sense,

constantly decreasing, excepting in III, where 1.20 is a great

deal too low. $\frac{\text{Na}_2\text{O} + \text{K}_2\text{O}}{\text{SiO}_2}$ is at the same time decreasing from

left to right as is also $\frac{\text{Na}_2\text{O}}{\text{SiO}_2}$.

For the San José district, soda increases at the expense of potash, as silica decreases with reference to the combined alkalis and to soda alone. At the same time ferric iron is gaining over ferrous iron.

PLATE VIII.

(297)

PLATE VIII.

Scale : 2 inches = 1 mile.

3 cm. = 1 kilometer.

(298)

GEOLOGICAL MAP
OF THE
SAN JOSE DISTRICT
TAMAULIPAS, MEXICO

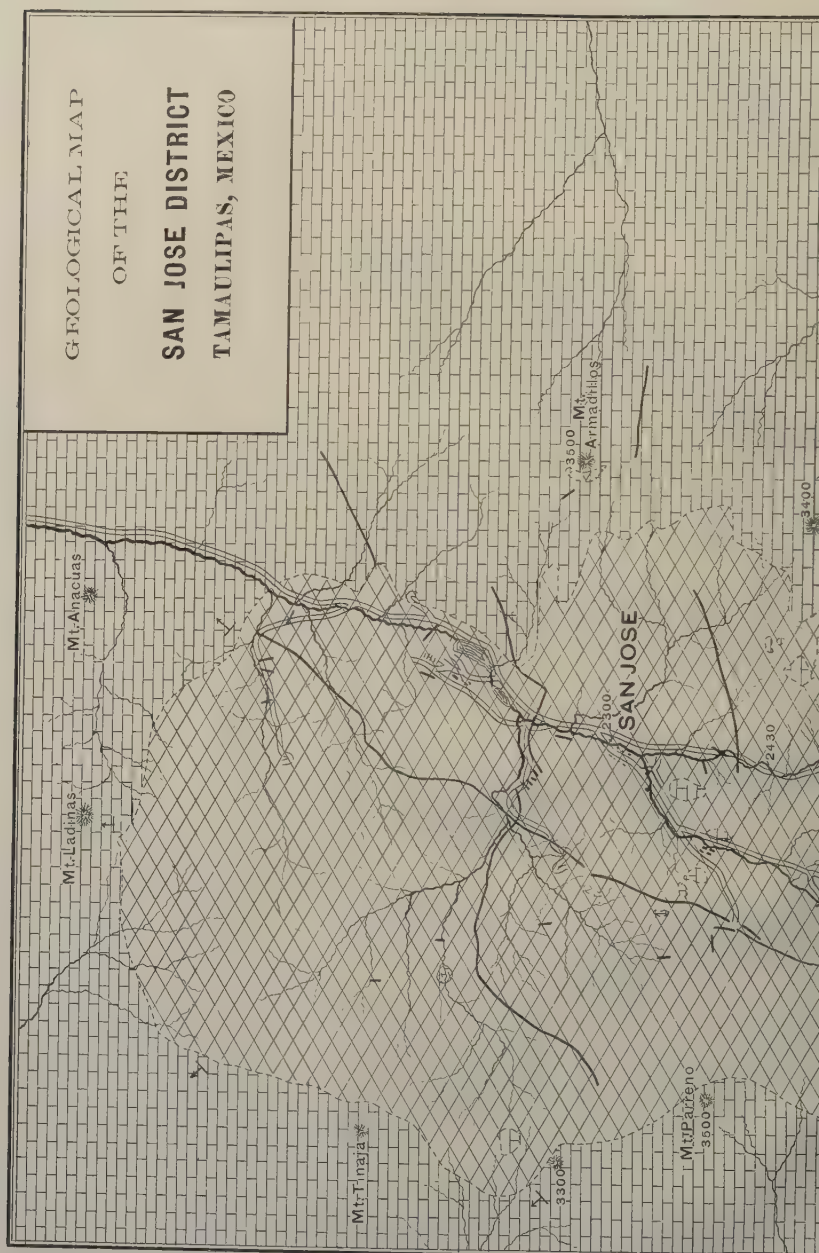
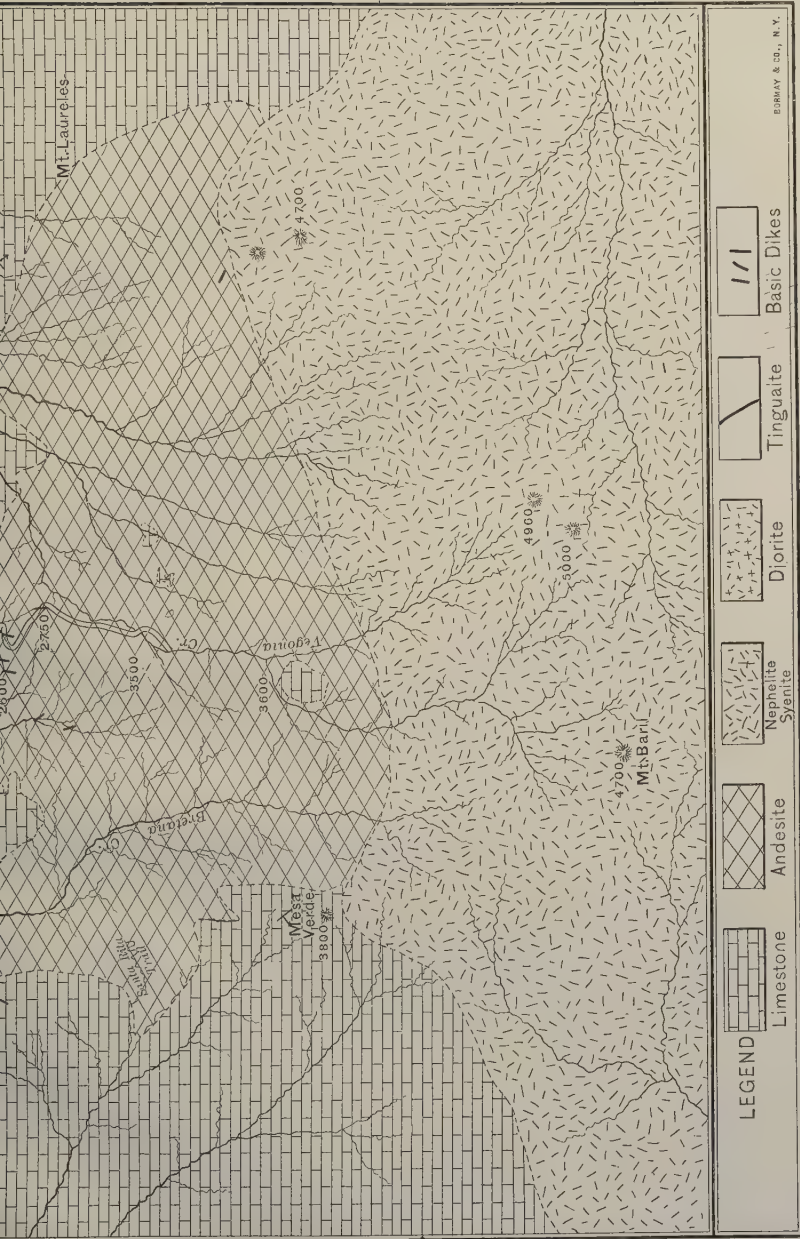


PLATE VIII.



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PLATE IX.

(299)

PLATE IX.

- Fig. 1. Nephelite Syenite. Ordinary Light. $\times 33$. The larger grain of magnetite is surrounded by clear, crystalline nephelite, and by augite. Kaolinized orthoclase appears in the upper part of the figure.
- Fig. 2. Syenitic Dike Rock. Ordinary Light. $\times 33$. The dark mineral is green fibrous hornblende. The colorless portions in the figure are orthoclase.

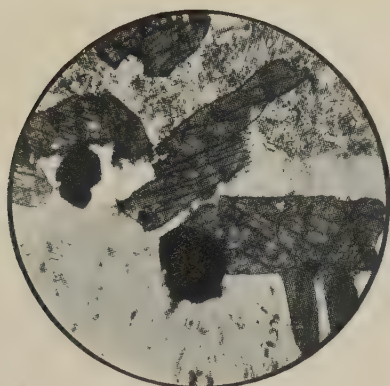


FIG. 1.

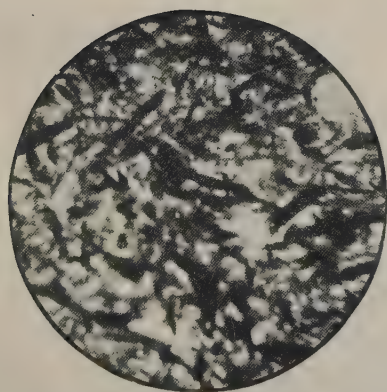


FIG. 2.

PLATE X.

(301)

PLATE X.

- Fig. 1. Nephelite Syenite. Crossed Nicols. $\times 33$. The lozenge-shaped crystal is titanite. The grayish mineral below it is nephelite. Orthoclase appears in the dark and light areas above.
- Fig. 2. Tinguaita. Crossed Nicols. $\times 33$. The ground-mass consists of ægirite needles and irregular pieces of feldspar. The porphyritic crystal is orthoclase.

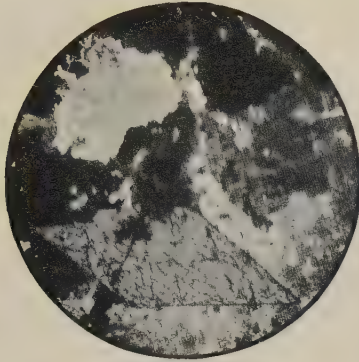


FIG. 1.

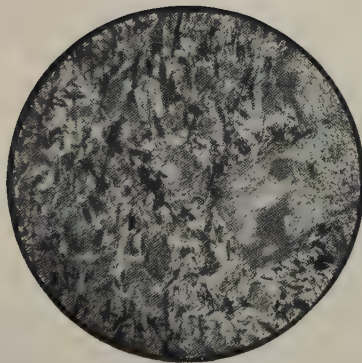


FIG. 2.

PLATE XI.

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PLATE XI.

- Fig. 1. Tinguaita. Crossed Nicols. $\times 33$. Crystal of nephelite in ground-mass of ægirite and feldspar.
- Fig. 2. Tinguaita. Crossed Nicols. $\times 33$. The phenocryst is of weathered and corroded feldspar. The replacement by secondary minerals, beginning at the periphery of the crystal, is first by a zone of feldspar rods, and intergrown pyroxene needles. The dark zone is of analcite. The colorless central portion is orthoclase.

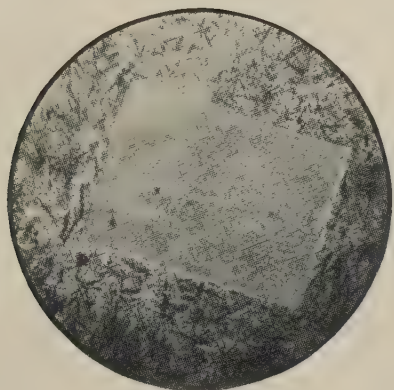


FIG. 1.

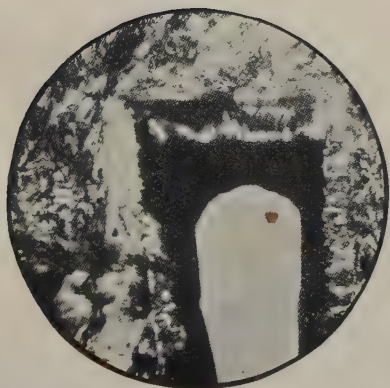


FIG. 2.

PLATE XII.

(305)

PLATE XII.

- Fig. 1. Andesite. Crossed Nicols. $\times 33$. Crystals of plagioclase feldspar in a crystalline ground-mass of feldspar and magnetic grains.
- Fig. 2. Diorite in ordinary light. $\times 33$. The colorless mineral is plagioclase. Augite appears above in contact with a large mass of magnetite, below bordering on a crystal of biotite.

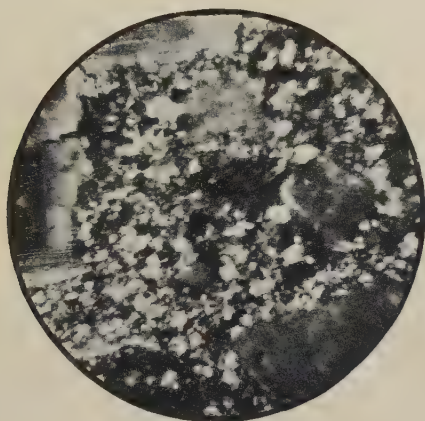


FIG. 1.

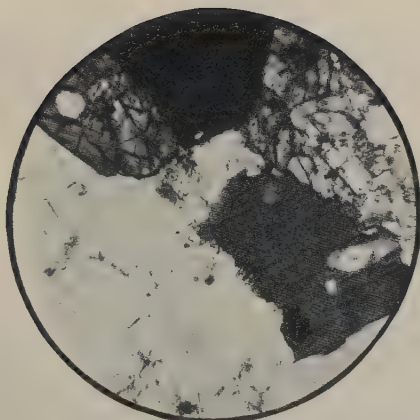


FIG. 2.

PLATE XIII.

(307)

PLATE XIII.

- Fig. 1. Limburgite Dike. Ordinary Light. $\times 33$. Crystals of colorless olivine in a ground-mass of augite, magnetite grains and brown glass.
- Fig. 2. Camptonite. Ordinary Light. $\times 33$. A phenocryst of augite appears in the lower left hand corner. The ground-mass is made up of hornblende prisms, irregular feldspar crystals (plagioclase) and grains of magnetite.

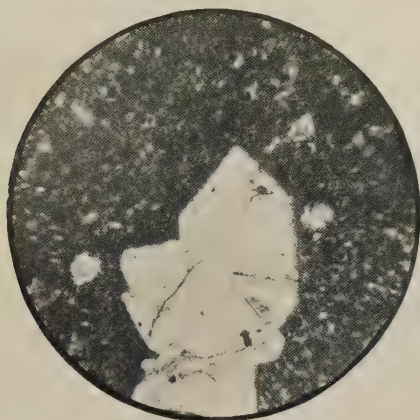


FIG. 1.

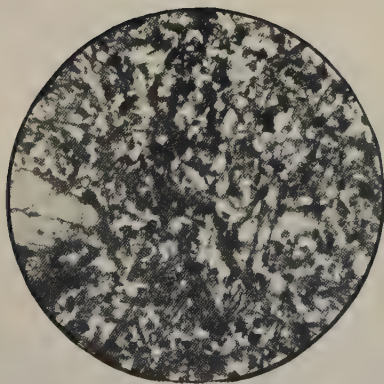


FIG. 2.

PLATE XIV.

(309)

PLATE XIV.

Piedra Iman, south of San José, at the Santa Helena mine. The mass in the center is of limestone included in the andesite. Mt. Armadillos on the left.



PLATE XV.

(311)

PLATE XV.

View from the west, looking across the San José valley toward Mt. Anacuas (left) and Mt. Armadillos (right). Limestone nearly horizontal capping andesite.



PLATE XVI.

(313)

PLATE XVI.

The San Carlos Mountains, (nephelite syenite), as seen from the Baril range, looking south across the Arroyo Grande.

(314)

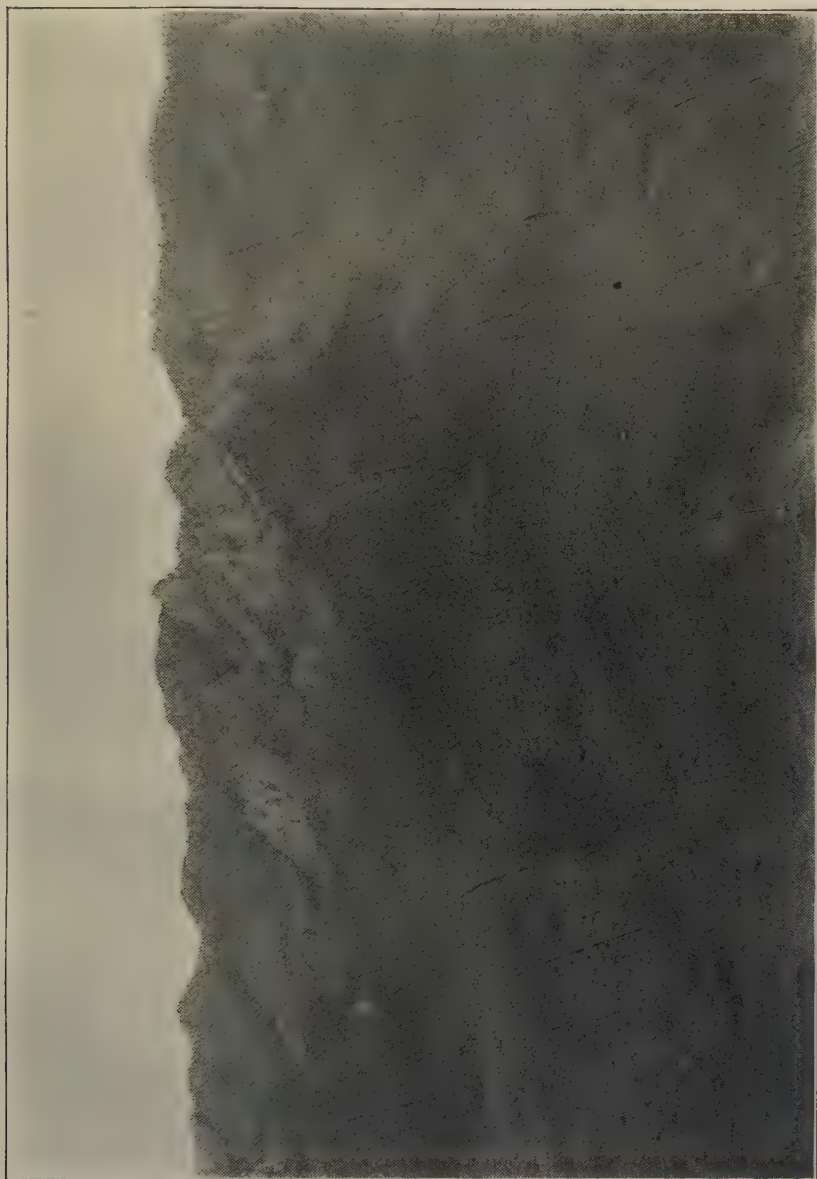


PLATE XVII.

(315)

PLATE XVII.

View looking southeast across the valley of the Arroyo Grande toward the town of San Carlos. The mountain slopes on both sides of the valley are of nephelite syenite.



PLATE XVIII.

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PLATE XVIII.

The Pic de Diablo from the head of Bocca de Alermos canyon.
Nephelite syenite.

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The Later Extinct Floras of North America, by JOHN STRONG NEWBERRY, a posthumous work, edited by Arthur Hollick; Monographs of the United States Geological Survey, Vol. XXXV. 4to, cloth, 295 pp., 68 pls., Washington [1899], may be obtained for \$1.25, by addressing the Director of the United States Geological Survey, Washington, D. C.

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